Mill Coulee and Muddy Creek Water Quality Assessment Project
Final Report - 2005

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Executive Summary

Evaluation of effectiveness of natural resource conservation practices, which involve voluntary implementation of Best Management Practices (BMPs), has gained substantial attention in the last several years. This report presents results of an assessment to determine whether natural resource management programs and BMPs implemented to enhance water quality and quantity within the Mill Coulee and Muddy Creek watersheds achieved their desired goals. Water quality parameters assessed included: specific conductance (electrical conductivity), nitrate + nitrite - N, phosphorus, suspended sediment concentration, pH, and selenium. Available water quality and quantity data was gathered and grouped into pre-EQIP and post-EQIP implementation periods. The grouped data sets were then compared statistically to determine significance of differences between the pre- and post-EQIP data sets. Efforts were undertaken to correlate significant differences between pre- and post-EQIP data to EQIP-related BMP implementation within each watershed. While lack of sufficient pre-EQIP water quantity and quality data precluded any valid statistical analysis for Mill Coulee, analyses conducted for Muddy Creek showed that there have been significant changes, deemed to be improvements, in water quality in Muddy Creek between the period prior to EQIP initiation and since EQIP initiation within the watershed. While it is difficult to say that a particular EQIP-sponsored or related practice implemented resulted in a specific change in any particular water quality parameter, decreases in water quantity between pre-EQIP and post-EQIP periods were not evident. Thus it would be valid to conclude that the improvements which are reflected as reductions in specific conductance, trends towards reductions in nitrate + nitrite – N concentrations, reductions in suspended sediment, and trends towards reductions in selenium concentration from the pre-EQIP to the post-EQIP period of study are a result of the practices implemented as a whole.

Overview/Preface

Mill Coulee and Muddy Creek are two tributaries of the Sun River, located in north central Montana. The Mill Coulee watershed consists of approximately 15,000 acres. Mill Coulee discharges into the Sun River near the community of Sun River, Montana. Mill Coulee is the primary surface drainage system for the Asheulot Bench. Deep percolation from irrigation return flow and drainage, surface discharges, and spillage all contribute to the perennial baseflow of Mill Coulee.

The Muddy Creek watershed consists of 314 mi^2. Muddy Creek flows approximately 40 miles in a southeast direction to its’ confluence with the Sun River just west of Great Falls. Muddy Creek typically exhibits an entrenched channel type

throughout. Return flows influence flows within Muddy Creek during the irrigation months.

Both Mill Coulee and Muddy Creek have historically been the subject of concern regarding water quality and quantity impairment discussions. The Sun River Watershed Group has invested many hours of time and effort to raise awareness and secure funds to help improve conditions within Muddy Creek and Mill Coulee. Additionally the Natural Resource Conservation Service (NRCS) has assisted with implementation of numerous projects to enhance water quality and quantity within these streams. Water quality and quantity were key concerns for Farm Bill funding received through Environmental Quality Incentive Program (EQIP) priority area dollars. EQIP county dollars, grant dollars, and practices funded by EQIP dollars have been put in place within the Muddy Creek and Mill Coulee watersheds. While extensive effort has been expended to make improvements in water quality and quantity in these two streams, there has never been a holistic assessment to determine whether the programs and practices implemented have achieved the intended goals.

Project Goal

The intent of this project was to determine whether projects, programs, and practices implemented within the Mill Coulee and Muddy Creek watersheds have resulted in definitive or quantifiable changes to Mill Coulee and Muddy Creek water quality and quantity. This project did not attempt to determine the success of individual projects or practices, but rather the project addressed the collective effectiveness of the implementation of EQIP programs as a whole across the watersheds.

Approach

To assess the outcomes of implemented programs and practices on Mill Coulee and Muddy Creek, the following tasks were accomplished. Simplistically stated, the approach was to gather, inspect, and group existing data between pre-EQIP and post-EQIP implementation periods, sort and analyze the data to determine significance of differences between the pre- and post-EQIP data sets, and finally attempt to correlate any significant differences in pre- and post-EQIP data to EQIP-related BMP implementation within each watershed.

The first task was to determine whether there have been measurable changes, trends, or patterns in the water quality and quantity for Mill Coulee and Muddy Creek over time, extending from prior to implementation of EQIP practices to present. This task was to be completed using existing data only and without any additional (new) data collection. To accomplish this task, a number of activities were undertaken:

- MSU Extension water quality personnel gathered data from a variety of sources including the USGS, DNRC, Sun River Watershed Group, and NRCS.

- **Data were grouped** by water quality parameter and flow **into two different time periods, pre-EQIP initiation** and **post-EQIP initiation**. A significant number of best management practices (BMP) targeted to soil, water, and land

resource improvements were implemented within the Muddy Creek watershed between 1996 and the present; correspondingly, **1996 to 2005 was determined to be the post-EQIP period for the Muddy Creek watershed, and years preceding 1996 were determined to be the pre-EQIP period for the Muddy Creek watershed.** Implementation of EQIP-associated BMPs in the Mill Coulee watershed started around 2000; **thus the post-EQIP period for Mill Coulee watershed was determined to be 2000 to 2005, and the pre-EQIP period for Mill Coulee watershed was determined to be all years preceding 2000.**

- After data were grouped by water quality parameter and then into pre-EQIP and post-EQIP periods for each stream, **data were sorted by flow volume.** Since most water quality parameters are directly influenced by flow characteristics, i.e., either increasing or decreasing as a result of flow, it was determined to complete analyses of selected water quality parameters based on flow levels. Muddy Creek data was grouped into five different flow groups: Low Flow < 80 cfs; Moderate Flow 80 – 165 cfs; High Flow 1 > 165 cfs; High Flow 2 > 80 cfs; Composite – all flows. No grouping by flow was done for Mill Coulee data, mainly because of lack of sufficient flow data to define a representative database and lack of extreme variability in the existing flow data.

- **Water quality parameters were then analyzed using an independent samples t-test** to ascertain whether significant differences were present at the 95% level of confidence ($P = 0.05$). **The independent samples t-test compares the means** of a variable for two independent data sets; for instance, the mean dissolved oxygen concentration for pre-EQIP and post-EQIP for Muddy Creek. Statistical analyses were completed using SPSS version 12.0 statistical analysis software.

<u>The second task</u> of this project was to determine **what EQIP-related activities/programs have been implemented within the watersheds** and the outcomes **of which could have effects on water quality and quantity in Mill Coulee and Muddy** Creek. Data were collected from NRCS offices in Teton and Cascade counties, which have made efforts to catalog all programs and practices that have been implemented in these two watersheds.

<u>The third task</u> of this project was to determine if correlations exist between pre- and post-EQIP implementation periods and changes or significant differences in pre- and post-EQIP water quality and quantity characteristics in Mill Coulee and Muddy Creek. Attempts were made to determine whether changes and trends found in water quality and quantity in Muddy Creek between the pre-EQIP and post-EQIP periods could be correlated with NRCS-funded practices and programs implemented within the Muddy Creek watershed. Due to a lack of pre-EQIP data for Mill Coulee, assessment of correlations was not possible for Mill Coulee.

Muddy Creek Water Quality Analysis

Six water quality parameters were analyzed to determine the degree and significance of differences in selected water quality characteristics for which data were available for Muddy Creek and Mill Coulee between pre-EQIP and post-EQIP years. Parameters for which data analyses were completed included: specific conductance (electrical conductivity), nitrate + nitrite - N, phosphorus, suspended sediment concentration, pH, and selenium. Data for all six of these parameters existed for samples collected at the Muddy Creek at Vaughn USGS gauging station. Additionally, suspended sediment concentration, conductivity, and nitrate + nitrite - N data from the Muddy Creek near Vaughn (Gordon) USGS gauging station were also analyzed.

The following tables present analyses results for Muddy Creek water quality parameters. Each table presents results for a specific water quality parameter. Each table includes means, standard deviations, and sample size notations (n) for pre-EQIP and post-EQIP data sets for each previously described flow group (low, moderate, high 1, high 2, and composite groupings for Muddy Creek data). Additionally significance levels of differences are reported in the tables. **A level of significance of difference less than 0.05 was used as the criteria for representation of significant difference between pre-EQIP and post-EQIP data sets.** Each table, based on reported significance levels of difference, defines whether there was a significant decrease, significant increase, or no significant difference between pre-EQIP and post-EQIP parameter means.

PARAMETER	**FLOW STRATIFICATION**				
Conductivity (*u*S/cm) **MC at Vaughn**	**Low**	**Moderate**	**High 1**	**High 2**	**Composite**
Pre EQIP: 1986-1995; Post-EQIP: 1996-2005	*<80 cfs*	*80-165 cfs*	*>165 cfs*	*> 80 cfs*	*All Flows*
Pre-EQIP Mean (*u*S/cm)	1274.3	770.7	799.1	787.6	1044.2
Std. Deviation	352.9	158.6	560.1	441.2	464.5
n	58	21	31	52	110
Post-EQIP Mean (*u*S/cm)	1094.4	701.0	630.1	648.5	847.4
Std. Deviation	443.7	401.0	163.5	246.7	412.3
n	62	20	57	77	139
Sign. Level of difference	0.02	0.47	0.04	0.02	0.00
Post-EQIP vs. Pre-EQIP	decrease	no difference	decrease	decrease	decrease

- Consistent decrease in conductivity (index of salinity) from pre-EQIP to post-EQIP period, in Muddy Creek @ Vaughn, in all but moderate flow regime. The response across 4 out of 5 flow regimes suggests that the decrease in salinity is not a function of flow.

PARAMETER	**FLOW STRATIFICATION**				
Conductivity (*u*S/cm) MC near Vaughn (Gordon)	**Low**	**Moderate**	**High 1**	**High 2**	**Composite**
Pre-EQIP: 1980-1987, 1991-1992; Post-EQIP: 1996-2005	*<80 cfs*	*80-165 cfs*	*>165 cfs*	*> 80 cfs*	*All Flows*
Pre-EQIP Mean (*u*S/cm)	1240.3	798.5	842.9	826.0	1084.3
Std. Deviation	319.4	150.1	532.7	425.2	413.0
N	48	21	18	29	77
Post-EQIP Mean (*u*S/cm)	1020.5	649.2	645.3	646.6	838.2
Std. Deviation	445.8	104.6	133.1	123.2	378.9
N	62	20	39	59	121
Sign. level of difference	0.01	0.00	0.14*	0.03*	0.00
Post-EQIP vs. Pre-EQIP	decrease	decrease	no difference	decrease	decrease

*Levenes test for equal variances found that equal variances could not be assumed. Significant level of differences reflect this assumption.

- Consistent decrease in conductivity (index of salinity) from pre-EQIP to post-EQIP period, in Muddy Creek @ Gordon, except for ‘high 1’ flow regime. The response across 4 out of 5 flow regimes suggests that the decrease in salinity is not a function of flow.

PARAMETER	**FLOW STRATIFICATION**				
Nitrate + Nitrite - N MC at Vaughn (mg/L)	**Low**	**Moderate**	**High 1**	**High 2**	**Composite**
Pre-EQIP: 1973-1974, 1977-1982; Post-EQIP: 1996-1998, 2001-2005	*<80 cfs*	*80-165 cfs*	*>165 cfs*	*> 80 cfs*	*All Flows*
Pre-EQIP Mean (mg/L)	3.5	1.6	1.0	1.2	2.5
Std. Deviation	2.2	1.8	0.7	1.2	2.1
N	50	14	26	40	90
Post-EQIP Mean (mg/L)	3.2	1.2	1.1	1.1	1.9
Std. Deviation	1.2	1.4	0.3	0.8	1.4
N	20	11	23	34	54
Sign. level of difference	0.60	0.51	0.50	0.74	0.07
Post-EQIP vs. Pre-EQIP	no difference	no difference	no difference	no difference	no difference

- The data indicate insignificant increases or decreases in nitrate + nitrite – N concentrations in Muddy Creek @ Vaughn from the pre-EQIP to the post-EQIP period, for any flow regime.

PARAMETER **MC near Vaughn (Gordon)**	**FLOW STRATIFICATION**				
Nitrite + Nitrate – N (mg/L)	**Low**	**Moderate**	**High 1**	**High 2**	**Composite**
Pre-EQIP: 1974-1982; Post-EQIP: 1996-2004	*<80 cfs*	*80-165 cfs*	*>165 cfs*	*> 80 cfs*	*All Flows*
Pre-EQIP Mean (mg/L)	4.47	2.52	2.19	2.33	3.48
Std. Deviation	2.44	2.46	3.96	3.35	3.08
N	60	23	29	52	112
Post-EQIP Mean (mg/L)	2.96	1.38	1.41	1.40	2.22
Std. Deviation	1.45	0.53	0.38	0.42	1.34
N	42	13	25	38	80
Sign. level of difference	0.00*	0.04*	0.30*	0.05*	0.00*
Post-EQIP vs. Pre-EQIP	decrease	decrease	no difference	decrease	decrease

*Levenes test for equal variances found that equal variances could not be assumed. Significant level of difference values reflect this assumption.

- Significant decrease in nitrate + nitrite – N concentration in Muddy Creek @ Gordon from the pre-EQIP to post-EQIP period, in all but the 'high 1' flow regime. This response suggests that the nitrate + nitrite – N concentration decrease from the pre-EQIP to the post-EQIP period is not a function of flow.

PARAMETER	**FLOW STRATIFICATION**				
Phosphorus (mg/L) **MC at Vaughn**	**Low**	**Moderate**	**High 1**	**High 2**	**Composite**
Pre-EQIP: 1977-1982, 1992-1995; Post-EQIP: 1996 – 2005	*<80 cfs*	*80-165 cfs*	*>165 cfs*	*> 80 cfs*	*All Flows*
Pre-EQIP Mean (mg/L)	0.02	0.02	0.02	0.03	0.02
Std. Deviation	0.05	0.01	0.03	0.03	0.04
N	40	15	27	42	82
Post-EQIP Mean (mg/L)	0.06	0.17	0.23	0.21	0.16
Std. Deviation	0.06	0.04	0.27	0.24	0.22
N	26	18	39	57	83
Sign. level of difference	0.04	0.00	0.00	0.00	0.00
Post-EQIP vs. Pre-EQIP	increase	increase	increase	increase	increase

Note – All Pre-EQIP data for phosphorus values were determined from analyses of filtered samples, all post-EQIP phosphorus values were determined from analyses of unfiltered samples.

- Although the analysis indicates an increase in phosphorus from the pre-EQIP to the post-EQIP period, the increase may merely be a reflection of change in sample

handling and analytical procedures. One would expect that phosphorus concentrations of unfiltered samples would be greater than phosphorus concentrations of the same samples following filtering.

PARAMETER	**FLOW STRATIFICATION**				
Suspended Sediment Concentration (mg/L) MC at Vaughn	**Low**	**Moderate**	**High 1**	**High 2**	**Composite**
Pre-EQIP: 1976-1981, 1992-1995; Post-EQIP: 1996-2005	*<80 cfs*	*80-165 cfs*	*>165 cfs*	*> 80 cfs*	*All Flows*
Pre-EQIP Mean (mg/L)	196.6	579.3	4943.0	3342.9	2341.8
Std. Deviation	254.6	541.0	5810.7	5062.9	4416.3
n	14	11	19	30	44
Post-EQIP Mean (mg/L)	64.6	252.0	343.1	316.5	202.0
Std. Deviation	54.2	172.1	464.3	401.7	323.1
n	40	14	34	48	88
Sign. level of difference	0.08*	0.08*	0.00*	0.00*	0.00*
Post-EQIP vs. Pre-EQIP	no difference	no difference	decrease	decrease	decrease

*Levenes test for equal variances found that equal variances could not be assumed. Significant level of difference values reflect this assumption.

- Significant reduction in sediment concentration in Muddy Creek @ Vaughn from the pre-EQIP to post-EQIP period under high flow conditions. In as much as decreases in sediment are not evident during the low flow conditions, it is reasonable to conclude that management practices related to bank and bottom stabilization have been one operative factor responsible for sediment reductions. Sediment sourcing during high-flow conditions is primarily bank slough and bottom scour. In as much as the same condition is observed at the up-stream sampling location (Gordon, next table) for all flow regimes, it's reasonable to assume that land and water management practices up-gradient of the Gordon station have resulted in significant reductions in sediment from the pre-EQIP to the post-EQIP period.

PARAMETER	**FLOW STRATIFICATION**		
Suspended Sediment Concentration (mg/L) MC near Vaughn (Gordon)	**Low/Moderate**	**High**	**Composite**
Pre-EQIP: 1973-1982; Post-EQIP: 1996-2005	*<165cfs*	*>165 cfs*	*All Flows*
Pre-EQIP Mean (mg/L)	1008.0	4538.3	3408.6
Std. Deviation	692.7	3918.6	3633.4
n	8	17	25
Post-EQIP Mean (mg/L)	83.3	190.5	115.7
Std. Deviation	81.8	176.0	127.4

n	60	28	86
Sign. level of difference	0.01*	0.00*	0.00*
Post-EQIP vs. Pre-EQIP	decrease	decrease	decrease

*Levenes test for equal variances found that equal variances could not be assumed. Levels of significance of differences reflect this assumption. Note: Due to differences in group sizes, flow grouping was reduced to only two regimes, in addition to the composite.

- Significant reduction in sediment concentration in Muddy Creek @ Vaughn from the pre-EQIP to post-EQIP period under high flow conditions. In as much as the reduction in sediment @ Gordon between the pre-EQIP and post-EQIP periods occurred for all flow regimes, it's reasonable to assume that land and water management practices up-gradient of the Gordon station have resulted in significant reductions of sediment sources from tributaries originating within Greenfield's Irrigation District.

PARAMETER	**FLOW STRATIFICATION**				
pH MC at Vaughn	**Low**	**Moderate**	**High 1**	**High 2**	**Composite**
Pre-EQIP: 1978-1980, 1986, 1990-1992; Post-EQIP: 1999-2005	*<80 cfs*	*80-165 cfs*	*>165 cfs*	*> 80 cfs*	*All Flows*
Pre-EQIP Mean	8.31	8.37	8.17	8.24	8.30
Std. Deviation	0.34	0.10	0.35	0.30	0.32
n	16	6	13	19	35
Post-EQIP Mean	8.48	8.46	8.48	8.48	8.50
Std. Deviation	0.23	0.08	0.09	0.09	0.17
n	26	7	21	28	54
Sign. level of difference	0.08*	0.10	0.01*	0.00*	0.00*
Post-EQIP vs. Pre-EQIP	no difference	no difference	increase	increase	increase

*Levenes test for equal variances found that equal variances could not be assumed. Levels of significance of differences reflect this assumption.

- Increase in pH of Muddy Creek @ Vaughn between the pre-EQIP and post-EQIP periods and at higher flow regimes. These increases in pH may be a reflection of greater proportional contributions of surface flow, pass-through and lesser contributions of seepage and baseflow to total flow during the post-EQIP period.

PARAMETER	**FLOW STRATIFICATION**				
Selenium (*u*g/L) MC at Vaughn	**Low**	**Moderate**	**High 1**	**High 2**	**Composite**
Pre-EQIP: 1991-1995; Post-EQIP: 2000-2005	*<80 cfs*	*80-165 cfs*	*>165 cfs*	*> 80 cfs*	*All Flows*
Pre-EQIP Mean (*u*g/L)	5.88	1.80	2.20	2.07	4.09
Std. Deviation	2.20	1.30	0.63	0.88	2.57
n	17	5	10	15	32

Post-EQIP Mean (*u*g/L)	2.94	1.27	1.36	1.34	2.14
Std. Deviation	0.75	0.29	0.23	0.24	0.98
n	24	7	17	24	48
Sign. level of difference	0.00*	0.42*	0.00	0.01*	0.00*
Post-EQIP vs. Pre-EQIP	decrease	no difference	decrease	decrease	decrease

*Levenes test for equal variances found that equal variances could not be assumed. Levels of significance of differences reflect this assumption.

- Selenium concentration in Muddy Creek @ Vaughn decreased from the pre-EQIP to post-EQIP period for all flow regimes except the 'moderate' flow regime. The decrease at 4 of the 5 flow regimes suggests that the decrease in selenium from the pre-EQIP to post-EQIP period is not a function of flow regime. Selenium mobility is generally associated with sub-soil drainage and leaching. Correspondingly, it is reasonable to conclude that soil and water management activities and practices during the post-EQIP period have resulted in reductions in deep percolation and drainage contributions to Muddy Creek flow. This would be consistent with increases in pH in Muddy Creek between the pre-EQIP and post-EQIP periods.

Muddy Creek Water Quantity Analysis

To analyze flow characteristics within Muddy Creek and how flow might have differed between pre-EQIP and post-EQIP implementation, flow data collected by the USGS at the Vaughn stations was divided into four subsets corresponding to changes (distinctly recognizable periods) in the annual hydrologic cycle. January, February, and March flow data was partitioned out as one group. Flows within these months represent baseflow, and presumably are not influenced by rainfall, runoff, or irrigation return flows. April and May flow data was partitioned out as another group. April and May represent a period of spring snowmelt runoff and high rainfall, with little likelihood of contributions from irrigation return flow or irrigation system discharges/releases. Flows occurring in June, July, and August were grouped together as another group. These months represent the irrigation season, and thus discharges and diversions resulting from the irrigation season influence flows within these months. September, October, November, and December make up the final flow group. These finals months represent a period of stream recharge and a return to baseflow conditions.

With the exception of the high rainfall period (April and May), data for all periods were analyzed the same way. Data from each period were organized into three data sets: 1) daily mean flow during the period; 2) cumulative flow during the period for each year; and 3) the difference between the maximum and minimum flow value recorded each month.

Each set of data was analyzed with an independent samples t-test using SPSS statistical software, with the exception that daily mean flow was analyzed using R statistical software, version 2.1.1. SPSS software could not handle the number of cases this set of data presented.

As mentioned previously, April and May data were grouped differently for analysis. Data for these months were grouped into two data sets: 1) the difference between maximum and minimum flows on a daily basis; and 2) average daily flow, accounting for precipitation. The process used to account for precipitation was essentially intended to 'normalize' the average daily flow across different rainfall occurrences. The data were normalized and precipitation was accounted for in the following manner: the average daily flow value (cfs) was divided by (1 plus the 24-hour precipitation total of the previous day (in inches)). This normalizing to develop the second group of flow data provides a mechanism that takes into account the fact that the impact of precipitation on average daily flow is most likely reflected in flow of the day after the event. This normalizing provided a mechanism to account for differences in average daily flow between pre- and post-EQIP periods under circumstances when flow was predominantly affected by rainfall events.

Precipitation data was obtained from measurements made at the Great Falls airport and collected by the Western Regional Climate Center.

The following tables present flow analysis results. Each table presents results for a particular group of months and includes pre-EQIP and post-EQIP means, standard deviations, and sample size (n). Additionally, levels of significance of differences are reported. A significance level of difference less than 0.05 represents a significant change. Each table, based on reported level of significance of difference, defines whether there was a decrease, increase, or no difference between post-EQIP means and pre-EQIP means of flow.

PARAMETER		
Cumulative flow (acre-feet) for January, February, March	*Pre-EQIP 1987-1995*	*Post EQIP 1996-2004*
Mean (acre feet)	6,273.7	6,645.3
Std. Deviation	1,760.7	2,092.2
n	9	9
Sign. level of difference	0.69	
Post-EQIP vs. Pre-EQIP	no difference	

PARAMETER		
Difference between monthly max and min flows (cfs) for January, February, March	*Pre-EQIP 1987-1995*	*Post EQIP 1996-2004*
Mean	36.0	55.44
Std. Deviation	87.5	69.5
n	27	27
Sign. level of difference	0.34	
Post-EQIP vs. Pre-EQIP	no difference	

PARAMETER		
Daily mean flow (cfs) for January, February, March	*Pre-EQIP 1987-1995*	*Post EQIP 1996-2004*
Mean	35.1	37.2
Std. Deviation	25.4	24.4
n	813	813
Sign. level of difference	0.10*	
Post-EQIP vs. Pre-EQIP	no difference	

*Levenes test for equal variances found that equal variances could not be assumed. Significant level of difference values reflect this assumption.

Average daily flows (cfs) for April and May, normalized to account for precipitation	*Pre-EQIP 1987-1995*	*Post EQIP 1996-2004*
Mean (cfs)	81.4	76.1
Std. Deviation	63.3	65.2
n		
Sign. level of difference	0.17	
Post-EQIP vs. Pre-EQIP	no difference	

Difference between max and min flows (cfs) on a daily basis for April and May	*Pre-EQIP 1987-1995*	*Post EQIP 1996-2004*
Mean (cfs)	32.7	25.9
Std. Deviation	68.3	34.8
n	549	544
Sign. level of difference	0.04*	
Post-EQIP vs. Pre-EQIP	decrease	

*Levenes test for equal variances found that equal variances could not be assumed. Level of significance of difference in means reflects this assumption.

PARAMETER		
Cumulative flow (acre-feet) for June, July, August	*Pre-EQIP 1987-1995*	*Post EQIP 1996-2004*
Mean (acre feet)	47,723.3	48,490.0
Std. Deviation	7,899.2	4,611.0
n	9	9
Sign. level of difference	0.81	
Post-EQIP vs. Pre-EQIP	no difference	

PARAMETER		
Difference between monthly max and min flows (cfs) for June, July, August	*Pre-EQIP 1987-1995*	*Post EQIP 1996-2004*
Mean (cfs)	295.3	261.9
Std. Deviation	180.4	186.6
n	27	27
Sign. level of difference	0.51	
Post-EQIP vs. Pre-EQIP	no difference	

PARAMETER		
Daily mean flow (cfs) for June, July, August	*Pre-EQIP 1987-1995*	*Post EQIP 1996-2004*
Mean (cfs)	262.0	266.2
Std. Deviation	99.1	81.5
n	828	828
Sign. level of difference	0.35*	
Post-EQIP vs. Pre-EQIP	no difference	

*Levenes test for equal variances found that equal variances could not be assumed. Level of significance of difference in means reflects this assumption.

PARAMETER		
Cumulative flow (acre-feet) for September, October, November, December	*Pre-EQIP 1987-1995*	*Post EQIP 1996-2004*
Mean (acre feet)	19,304.4	20,250.2
Std. Deviation	2,437.8	4,773.8
n	9	9
Sign. level of difference	0.60	
Post-EQIP vs. Pre-EQIP	no difference	

Difference between monthly max and min flows (cfs) for September, October, November, December	*Pre-EQIP 1987-1995*	*Post EQIP 1996-2004*
Mean (cfs)	62.7	67.6
Std. Deviation	45.7	56.1
n	36	36
Sign. level of difference	0.69	
Post-EQIP vs. Pre-EQIP	no difference	

<u>Daily mean flow (cfs) for September, October, November, December</u>	*Pre-EQIP 1987-1995*	*Post EQIP 1996-2004*
Mean (cfs)	79.9	83.8
Std. Deviation	48.8	56.0
n	1098	1098
Sign. level of difference	0.08*	
<u>Post-EQIP vs. Pre-EQIP</u>	no difference	

*Levenes test for equal variances found that equal variances could not be assumed. Level of significance of difference in means reflects this assumption.

<u>Mill Coulee Water Quality and Quantity Analysis</u>

Most of the BMPs implemented within the Mill Coulee watershed, and associated with EQIP, have occurred since 2000. A regimented data set, reflecting water quality and quantity characteristics, has been collected during the past 5 years. Before 2000, which would be identified as pre-EQIP years, data gathering and monitoring water quality and quantity was minimal. Consequently, there are not sufficient data in the pre-EQIP era to allow for an accurate or representative evaluation of changes in Mill Coulee that might be attributable to post initiation of the EQIP conditions. No attempt was made to complete an analysis for pre and post-EQIP years. The available data is presented and summarized, provided as a baseline or reference, so that future analyses can be conducted to determine changes.

The following three tables summarize the limited water quality and flow data pertaining to Mill Coulee for pre-EQIP initiation years, that being time prior to 2000.

Data from USGS monitoring

Station: USGS 473241111422401 Mill Coulee at Hwy 89 nr Mouth nr Sun River MT						
Date	Parameter					
	Water Temperature (deg C)	Instantaneous Discharge (cfs)	Specific Conductance (uS/cm)	pH, water unfltrd	Selenium, fltrd (ug/L)	Selenium, unfltrd (ug/L)
11/15/90	5	8	1,240	8.5	<2	
5/1/91	8.5	5	1,590			2
3/31/92	4	6	1,340	8.4		2
5/7/92	12	15	843	8.3		1
Station: USGS 473322111450401 Mill Coulee at Hwy 89 nr Sun River MT						
11/15/90	5	5	1020	8.4	2	
Station: USGS 473330111453101 Mill Coulee trib nr Sun River MT						
11/15/90	5	0.1	1250	8.2	3	

Data from Upper Mill Coulee Stream Assessment done by NRCS – 1996

Location	Parameter				
	Flow (cfs)	NO3 (mg/L)	TKN (mg/L)	TP (mg/L)	TSS (mg/L)
Near Headwaters	43	<0.01	0.4	0.074	62.6
@ Hwy 89 Bridge	50	0.25	0.8	0.203	226.9

Data from "Water Quantity and Quality of the Sun River from Gibson Dam to Vaughn", 1973 – 1974 by William J Hill, MT Dept of Fish and Game

	1973	1974
Observations	6	7
Flow (cfs)	15	5-39
Turbidity	20-40 ppm SiO_2	12-170 JTU
TDS (ppm)		310-745
Temperature (deg F)	63-74	41-63

Flow data has been collected by DNRC staff using aquarod water level recorders at two locations on Mill Coulee – Upper and Lower since 2000. DNRC staff install the aquarods every spring, sometime during March and April, and pull them out around the end of October. The following table summarizes flows measured during the six-year period in Mill Coulee just before it discharges into the Sun River.

Months	Average Flow (cfs)
April, May	12.0
June, July, August	38.1
September, October	18.5

Water quality data have been collected by the Sun River Watershed Group during April - October and since 2001. The following table summarizes observations made during the past five years. The values reported in this table reflect averages of data collected at the Mill Coulee at Hwy 89 bridge sampling location. The table includes means, maximum and minimum values, standard deviations, and number of samples (n) for the dataset.

	Parameter								
	Water Temp (C)	pH	Nitrate+ Nitrite-N (mg/L)	TKN (mg/L)	Total Phos-phorus (mg/L)	TSS (mg/L)	Turbidity (NTU)	DO (mg/L)	Conductivity (mS/cm)
Max	18.8	9.6	3.0	2.4	0.3	148.0	132.0	14.7	1.5
Min	4.4	7.7	0.3	0.3	0.0	1.4	2.0	1.5	0.4
Average	12.4	8.5	1.1	0.7	0.1	46.4	29.8	10.0	0.8
Standard Deviation	3.7	0.5	0.8	0.6	0.1	44.4	31.3	3.0	0.4
N	23	23	20	13	19	17	22	22	23

*Note: Sample results reported as less than a particular number (<) are not included in this summary.

It is difficult to make any generalizations/conclusions about changes or differences in water quality and flow within Mill Coulee between pre-EQIP to post-EQIP years, based on the different types of water quality and flow data collected. The only two parameters that were collected in both pre-EQIP and post-EQIP years are pH and conductivity. pH values for the pre and post-EQIP periods remain within a relatively narrow and expected range, i.e., no obvious divergences or shifts in the range of pH values between the two periods. Conductivity values are reported in various units. The following conversion can be used to transform the data into approximations having identical units of measure: 1 mS/cm = 1000 uS/cm. Utilizing this conversion to transform the data to common units, it appears that the average conductivity calculated in post-EQIP years is less than any conductivity values measured in the 90s.

<u>Practices Implemented</u>

The following tables list practices/programs implemented in the Muddy Creek and Mill Coulee watersheds. Tables list information supplied by Teton and Cascade county NRCS offices. While these tables are intended to include all practices implemented within the Muddy Creek and Mill Coulee watersheds, it is possible that not all practices are included.

Muddy Creek (Teton County)

Location	Practice
22N 1W 15,16	irrigation water conveyance, pipeline, irrigation system, sprinkler, nutrient management
22N 1W 36	irrigation system, sprinkler, irrigation water management
22N 1W 31	irrigation-pipeline
22N 1W 28	irrigation water conveyance, pipeline, irrigation system, sprinkler, spoil/soil spreading, nutrient management
22N 1W 17, 18, 20, 29	irrigation system, sprinkler, irrigation water conveyance, irrigation water management
21N 4W 4	structure for water control, spoil/soil spreading, irrigation water conveyance, pipeline, irrigation system, sprinkler, critical area planting, nutrient management

Mill Coulee (Cascade County)

Location	Practice
21N 2W 25	irrigation water conservation, irrigation water management, crop rotation management, nutrient management, pest management
21N 2W 23	sprinkler, irrigation water management, conservation tillage, nutrient management, pest management, residue management
21N 2W 12	irrigation water management, ditch, irrigation water conveyance (lining), land smoothing
21N 2W 26	sprinkler, irrigation water conservation, structure for water control
21N 1W 19	irrigation water conservation, canal lining fence, hay planting, spring development, pipeline, tank

Summary/Conclusions

Muddy Creek Water Quality

The following table provides a summary of differences in identified water quality and quantity characterizations between Post-EQIP vs. Pre-EQIP conditions. Decrease or increase is reported only for those comparisons where the level of difference between pre and post-EQIP means was determined to be significant at the 0.05 probability level.

Parameter or flow characterization x flow regime	**Low Flow**	**Moderate Flow**	**High 1 Flow**	**High 2 Flow**	**Composite Flow**
Conductivity in MC @ Vaughn; (uS/cm)	decrease	no difference	decrease	decrease	decrease
Conductivity in MC @ Gordon; (uS/cm)	decrease	decrease	no difference	decrease	decrease
Nitrate + Nitrite - N in MC @ Vaughn; (mg/L)	no difference	no difference	no difference	no difference	no difference
Nitrite + nitrate – N in MC @ Gordon; (mg/L)	decrease	decrease	no difference	decrease	decrease
Phosphorus in MC @ Vaughn; (mg/L)	increase	increase	increase	increase	increase
Suspended Sediment Concentration in MC @ Vaughn; (mg/L)	no difference	no difference	decrease	decrease	decrease
Suspended Sediment Concentration in MC @ Gordon; (mg/L)	decrease	decrease	decrease		decrease
pH in MC @ Vaughn	no difference	no difference	increase	increase	increase
Selenium in MC @ Vaughn; (ug/L)	decrease	no difference	decrease	decrease	decrease
Flow characterization x hydrologic period of annual hydrograph	**January-March**	**April - May**	**June - August**	**September - December**	
Cumulative flow in MC @ Vaughn (acre-feet)	no difference	no difference	no difference	no difference	
Difference between monthly max and min flows @ Vaughn (cfs)	no difference	decrease	no difference	no difference	
Daily mean flow @ Vaughn (cfs)	no difference	no difference	no difference	no difference	

1. Conductivity levels, which were evaluated at both Vaughn and Gordon, generally decreased from pre-EQIP to post-EQIP period. All mean conductivity levels were less in post-EQIP years than pre-EQIP years. This pattern was observed under all flow levels, suggesting that a reduction in salinity has occurred on a watershed scale and is not flow-dependent.

2. Statistical analyses found that there were no significant differences between post and pre-EQIP period nitrate + nitrite – N concentration means, measured at Vaughn. Yet, means show that generally there was a small decrease in nitrate + nitrite – N concentration from the pre to post-EQIP period. Nitrate + nitrite – N levels measured at Gordon show significant decreases between pre and post-EQIP levels in four of the five flow categories measured.

3. Phosphorus concentrations actually increase from pre to post-EQIP years. This analysis and outcome is subject to question, however. All pre-EQIP data for phosphorus were determined from analyses on filtered samples and all post-EQIP data were derived from analyses of unfiltered samples. The significant increases measured are not necessarily a result of real stream conditions, but rather the way in which samples were analyzed. In as much as in-stream phosphorus is generally associated with adsorption to soil particulate matter (sediment), sample filtration prior to analyses will result in measurement of only soluble phosphorus, whereas analyses of unfiltered samples will result in measurement of both soluble and particulate or adsorbed phosphorus. The latter phosphorus meteric is likely to be greater than the former in most cases where sediment impairment is present – as is the case with Muddy Creek.

4. With the exception of two flow groups, significant decreases in suspended sediment concentration were measured from pre to post-EQIP years, based on samples taken at either Vaughn or Gordon. The two flow groups, both in the lower flow regimes, that did not show significant decreases in phosphorus concentration at the 95% confidence level between the pre and post-EQIP periods would have shown significant decreases in phosphorus between the pre and post-EQIP periods at the 90% level of confidence.

5. pH values significantly increased from pre to post-EQIP years within the higher flow regimes. There was also an increase in pH levels in the lower pH regimes, which would be significant at the 90% confidence level. Changes in pH could be the result of three separate circumstances: 1) increased (proportional) contributions of seepage and subsurface drain water to baseflow within Muddy Creek following EQIP initiation; 2) increases in surface runoff and surface-associated irrigation return flow (proportional) contributions to in-stream flow subsequent to EQIP initiation; or 3) increased (proportional) contributions to stream flow from irrigation system delivery wastewater and operational spillage having a higher pH (more alkaline) chemistry than baseflow.

6. Selenium significantly decreased from pre to post-EQIP years. Only within the moderate flow category were significant decreases not measured, yet mean

selenium concentrations indicated a trend toward decreases from pre to post-EQIP years.

7. On the whole water quality within Muddy Creek was determined through these comparative analyses to be significantly better in post-EQIP years than in the pre-EQIP years, based on the supposition that the significant differences identified between pre and post-EQIP periods are deemed ‘improvements’. From the perspective of this study, improvements are reflected as: reductions in specific conductance, trends towards reductions in nitrate + nitrite – N concentrations, reductions in suspended sediment, and trends towards reductions in selenium concentration from the pre-EQIP to the post-EQIP period of study.

Muddy Creek Water Quantity

1. Significant differences in flow between the pre and post-EQIP periods during the months of January, February, and March were not measured. Although not significant, mean flows suggested a trend toward some increase in flow between pre and post-EQIP years.

2. The difference between the daily maximum and minimum flows for April and May, i.e., the amplitude of stream flow fluctuation, recorded on a daily basis, decreased significantly between the pre and post-EQIP years. There was not a significant difference between maximum and minimum flow between the pre and post-EQIP periods when precipitation data was included in the analysis.

3. A difference in June, July and August mean daily flow between the pre-EQIP and post-EQIP period was calculated. However, the difference in June, July, and August mean daily flow between the pre-EQIP and post-EQIP periods was not significant. Mean daily flow increased slightly from the pre to post-EQIP period.

4. Differences in mean daily flow during September, October, November, and December between the pre-EQIP period and the post-EQIP period were not significant. Mean daily flow during September, October, November, and December increases slightly (not significant) between the pre-EQIP and post-EQIP years.

5. On the whole, flow volumes were not significantly different between pre-EQIP and post-EQIP periods.

Mill Coulee Water Quality and Quantity

Insufficient data was available for the pre-EQIP period for Mill Coulee. Thus, it was not possible to perform valid statistical analyses.

Correlations between EQIP projects and water quality and quantity in Muddy Creek

The analyses conducted showed that there have been significant changes, in this case deemed to be improvements, in water quality in Muddy Creek between the period prior to EQIP initiation and since EQIP initiation within the watershed. While it is difficult to say that a particular EQIP-sponsored or related practice that has been implemented has resulted in a particular decrease in a certain water quality parameter, it is possible to make some basic generalizations. The table on page 15 for Muddy Creek practices implemented shows an extensive list of BMPs that have been shown to result in improved water quality. Since significant decreases in water quantity between pre-EQIP and post-EQIP periods were not measured, it would be valid to conclude that the enhanced water quality is a result of the practices implemented as a whole.

Additional data/follow-up

In order to determine changes in water quality and quantity data over years and to document improvements, continuous, planned and coordinated water quality and flow monitoring is essential. It is also necessary to make the same types of measurements, using the same type of analysis procedures each year in the same locations so that valid analyses to determine changes in water quality can be determined. Collection of water quality data without associated water quantity data makes implementation effectiveness analyses difficult and the interpretations of results are subject to question. It would be beneficial to develop a comprehensive and holistic water resource assessment and reporting plan, including standard operating procedures guidelines, and quality assurance and quality control protocols, for both Muddy Creek and Mill Coulee in the event this type of analysis is to be completed again or in the event more practice and program implementation continues within the Mill Coulee and Muddy Creek.

The challenges of this study clearly point out the importance of pre-program implementation monitoring and data gathering. Baseline event and ambient water quality and quantity characterization is essential to program effectiveness assessment when the objective of program implementation is water quality improvement – as is the case with EQIP.